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The Starburst-AGN connection: Implications for the Unification of Seyferts

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Abstract.

Observations at ultraviolet, optical and near-infrared wavelengths have shown the existence of recent star formation in the nuclear regions of Seyfert 2 (Sy2) galaxies that suggest a connection between the Starburst and the Seyfert phenomenon. According with the standard unified models of AGN circumnuclear starbursts also have to be present (and in the same numbers) in Sy1 as in Sy2 galaxies. This review discuss evidence in favor of the Starburst-AGN connection, as well as possible differences in terms of star formation activity between Sy1 and Sy2, that suggest an alternative interpretation of the Seyfert classification to that proposed by the standard unification model. Figures illustrating this contribution can be found in: http://www.iaa.csic.es/~rosa/

1. Introduction

One of the most important questions concerning the active galactic nuclei (AGN) phenomenon is the connection between Starburst and Quasar activity. There is evidence that suggests that circumnuclear starbursts can have bolometric luminosities that rival even powerful Quasar. The ubiquity of super-massive black holes in the nuclei of normal galaxies (Kormendy & Ho 2000) and the proportionality between the black hole and the spheroidal masses (Ferrarese & Merrit 2000; Gerbhard et al 2000) suggest that the creation of a black hole was an integral part of the formation of ellipticals and the bulge of spirals. In consequence, violent events of star formation and AGN can coexist together and probably they did in the past even more often that we observe today.

The role of starbursts in AGN has been extensively discussed theoretically in the past. An indirect connection between the two phenomena can exist because both are triggered by and live on gas fueling (mergers, interactions between galaxies, bars; e.g. Mihos & Hernquist 1996; Shlosman & Noguchi, 1993). However, symbiotic processes between stars and the black hole (Perry & Dyson 1985; Norman & Scoville 1988; Willians et al 1999; Colin & Zahn 2000), the evolution of starburst as the origin of the AGN activity (Terlevich & Melnick 1985; Terlevich et al 1992), or the interaction of the AGN with the interstellar medium (e.g. van Breugel et al 1985; van Breugel & Dey 1993; Ohsuga & Umemura 1999) are examples of a more direct connection between starbursts and AGN.

A starburst-AGN connection is also proposed to solve a series of puzzles and paradoxes involving the unification model of AGN. According to the unified picture, the blue continuum (called the 'featureless continuum', or FC) observed in Sy2 galaxies was believed to be scattered light from the hidden Sy1 nucleus. However, this interpretation is not completely correct because after the contribution of the old stars is removed, the remaining optical continuum has a significantly lower fractional polarization than the broad optical emission lines (Tran 1995). Therefore another unpolarized component has to contribute to the FC. Tran (1995) suggests that the unpolarized component is optically thin thermal emission from warm gas, that is heated by the central hidden source. In contrast, Cid-Fernandes & Terlevich (1995) and Heckman et al. (1995) suggest that the unpolarized component is a young but dust-reddened stellar population, possibly associated with the obscuring torus.

This paper presents evidence of the existence of young stars in the nuclei of Seyfert and Radio galaxies that strongly suggest a connection between the two phenomena. Most of the results discussed here are found through the detection of stellar absorption lines produced by young stars in the nuclei of AGN. However, other evidence has been recently found by studying the circumnuclear nebular optical emission lines in Seyferts (e.g. Goncalves & Veron 1999; Kewley et al 2001).

2. Evidence of young stars in low luminosity AGN: Seyfert galaxies

2.1. UV morphology

Starbursts are very bright at ultraviolet (UV) wavelengths because they are powered by massive stars which emit most of their flux at these and shorter wavelengths. UV images of starbursts show that a significant fraction of the young stars form in very compact stellar clusters with size of a few pcs. Therefore, the UV morphology provides direct evidence of the location of the most recent unobscured star forming regions.

HST images of Sy2 galaxies have revealed that most of the UV continuum is produced by a spatially resolved nuclear starburst (Figure 1), showing subarcsec structures that may be produced by super stellar clusters. The effective radius of the continuum emission ($\sim$100 pc) is similar to the size of the NLR (González Delgado et al 1998). In contract, the UV continuum light provided by the active nucleus is very little ($\leq$ 20%, Colina et al 1997; González Delgado et al 1998). Circumnuclear starbursts have been found also in Sy1 galaxies (e.g. NGC 7469, proposal 6358, P.I. Colina). However, a quick analysis of HST archival data of available UV imaging of nearby Sy1, indicates that in many Sy1 galaxies, the UV light is emitted only by a central unresolved knot (e.g NGC 3227, proposal 6837, P.I. Ho) (Figure 1). This may be interpreted as a larger frequency of nuclear star formation in Sy2 than in Sy1 and it would imply an intrinsic difference between type 1 and type 2. Therefore, it could present an evidence against the unification model. However, a systematic study of Sy1 as in Sy2 has not been done yet. On the other hand, a compact UV morphology by itself is not enough proof to exclude the presence of massive stars in the nucleus of Sy1 galaxies.
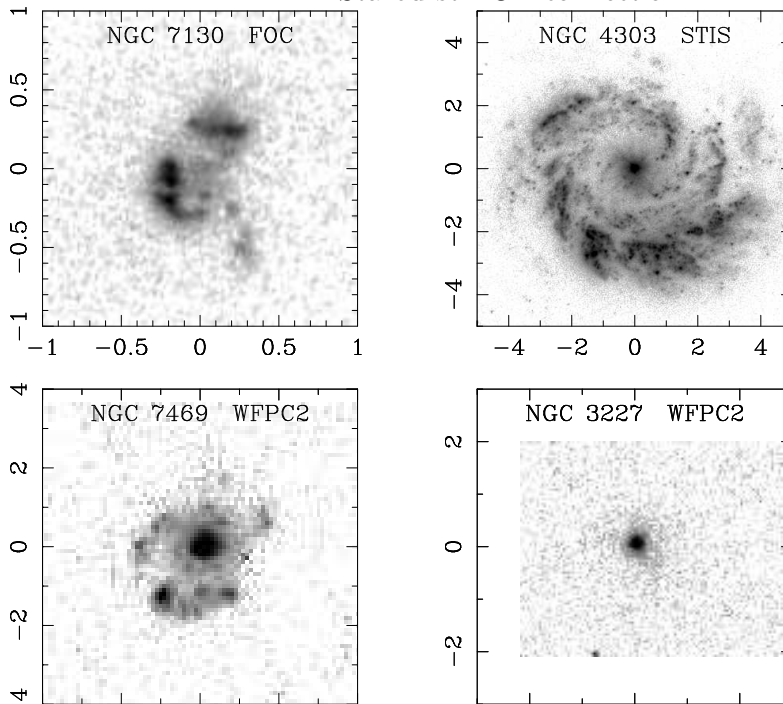
Figure 1. HST UV images of the Sy 2 and Sy 1 galaxies NGC 7130, NGC 4303 and NGC 7469 and NGC 3227. 1 arcsec corresponds to 310, 80, 315 and 75 pc, respectively.

2.2. UV wind lines

A more conclusive proof that the UV continuum in AGN is provided by a starburst is obtained by the detection of resonance wind lines (as NV $\lambda1240$, SiIV $\lambda1400$ and CIV $\lambda1550$) in their nuclear spectra. In starbursts, these lines show a P-Cygni profile and/or are shifted by $\sim$ 1000-3000 km s^{-1}. The shape of these lines depends on the content in massive stars and can be used to constrain the properties (age, and the slope and upper mass limit of the IMF) of the young stellar clusters. The detection of these lines in UV bright Sy2 nuclei (Figure 2 Heckman et al 1997; González Delgado et al 1998) strongly indicates that nuclear starbursts dominate the UV light and that they are responsible for the FC continuum in Sy2. These starbursts contribute significantly to the energetic of the AGN because they provide a bolometric luminosity ($\sim 10^{10}$-10^{11} L$\odot$) which is similar to the luminosity of the hidden Sy1 nucleus. A beautiful example has been observed recently by Colina et al (2001a) in the Sy2 galaxy NGC 4303. The UV image shows a circumnuclear spiraling ring of stellar clusters plus a central knot at the position where the NICMOS images suggest the location of AGN. STIS UV spectrum of the central knot shows strong P-Cygni wind lines that are very similar to those detected in the stellar clusters of the ring . The estimated mass (2-3 10^5 M$\odot$) and bolometric luminosity ($\sim$ 2 10^8 L$\odot$) of this central knot is also similar to that estimated for super stellar clusters.

Figure 2.   GHRS UV nuclear (1.7×1.7 arcsec) spectrum of the Sy 2
galaxy NGC 7130 (a) and STIS UV nuclear (∼20 pc) spectrum of the
Sy 2 galaxy NGC 4303 and two stellar clusters (b).

2.3.   Wolf-Rayet features

Starbursts go through the Wolf-Rayet phase when stars more massive than 40
$M\odot$ evolve from the main sequence a few Myr after the onset of the burst. In
this phase, the optical spectra of starbursts show broad emission features at ∼
4660 Å, mainly due to NIII λ4634-4642 and HeII λ4686 produced by WN stars,
and at 5808 Å due to CIV (if WC stars form in the starburst).

These features have been detected in some Sy2 (Figure 3, Heckman et al
1997; Storchi-Bergmann et al 1997; Kunth & Contini 1999; Tran et al 1999;
González Delgado et al 2001). However, the most spectacular case has been
found in Mrk 477 (Heckman et al 1997) which is the most powerful Sy2 nucleus
in the local universe. The non detection of a broad HeII line in the polarized
spectrum (Tran 1995) and the finding of the wind lines NV λ1240 and SiIV
λ1400 suggest that the broad 4660 Å feature is provided by an ensemble of
about 30000 Wolf-Rayet of a stellar cluster that is 6 Myr old.

2.4.   Near-UV and optical stellar absorption lines

Massive stars also show photospheric absorption features (most notably the H
Balmer series and HeI lines). Even though many of the photospheric lines in
starbursts could be masked by the nebular lines in emission, the high-order
Balmer series (HOBS) and some of the HeI lines (λ3819, 4026, 4387 and 4922)
could be detected in absorption. This is because the strength of the Balmer
series in emission decreases rapidly with decreasing wavelength, whereas the
equivalent width of the stellar absorption lines is constant or increases with
wavelength (González Delgado, Leitherer & Heckman 1999). In fact, in the
Sy2 in which UV stellar wind resonance lines have been detected, have also the
HOBS and HeI in absorption.

González Delgado et al (2001, GD01) and Storchi-Bergmann et al (2000,
S00) have observed the near-UV spectra of 20 Sy2 galaxies each. The targets of
the two samples were selected by their nuclear nebular emission [OIII] λ5007 and
they represent the more powerful AGN in terms of their high excitation gas. The
criteria used to select the objects guarantee that the two samples are unbiased
towards presence or absence of starbursts. The nuclear spectra (corresponding to

Figure 3. Near-UV nuclear spectra of Sy2 galaxies that show the HOBS in absorption (a) and Wolf-Rayet features (b)

a few hundred pcs) show the HOBS and HeI lines in absorption in about 50% of the GD01 and 30% of the S00 samples (Figure 3). Then, young and intermediate stars dominate the optical continuum in about half of these powerful Sy2 nuclei. Recently, Cid Fernandes et al (2001; CF01) have re-analyzed the two samples using as starburst diagnostics the equivalent width of the metallic line Ca K and two near-UV colors (F_{3660}/F_{4020} and F_{4510}/F_{4020}). They find that the nuclei that harbor a starburst (as detected by the UV wind lines, HOBS or Wolf-Rayet features) also have the CaK line very diluted (Ew(Ca K) $\leq$ 10 Å), the old stellar population contributes less than 75% of the optical continuum, and more than 15% of the near-UV light is provided by the starburst. In addition, in $\sim$ 30% of the objects, a blue continuum is required to explain the dilution of the metallic lines. However, in these cases the FC continuum may be due to a young stellar population that is masked by the old population, or is scattered light provided by the hidden Sy1 nucleus. These results clearly indicate that at least 40% the most powerful Sy2 harbor a nuclear starburst and that it is responsible of the FC observed in most of these objects. On the other hand, the Sy2 with starbursts are also the brightest galaxies at the Far-Infrared ($L_{IR} \geq 2 \times 10^{10}$ L$\odot$) and they have the larger luminosity at mid-FIR (as estimated by the 12 μm IRAS band, GD01; CF01). This implies that young and intermediate populations are responsible of the FIR radiation, and the most powerful starbursts may be associated to the most powerful AGN.

2.5.   CaII triplet

In most of the Sy1 galaxies, the stellar features at the UV and optical wave-lengths, that are very good diagnostics to detect young stars in Sy2 galaxies, are masked by the broad nebular emission lines and by the AGN continuum. However, at the near-infrared, the CaII triplet (CaT: λ8498, 8542 and 8662 Å) is found in the nuclei of many Sy1 as strong as in Sy2 and normal galaxies. Therefore, this is a very good diagnostic to look for young stars in the nuclei of Seyfert galaxies and even more in Sy1. In fact, the CaT is a very good stellar diagnostic because it strongly depends on stellar surface gravity and to a less extent on metallicity (Díaz, Terlevich & Terlevich 1989). Thus, in starbursts younger than 1 Gyr, the strength of the lines is very sensitive to the relative number of red supergiant stars (RSG) (Mayya 1997; García-Vargas, Mollá & Bressan 1998).

Since the pioneering work by Terlevich, Díaz & Terlevich (1990), the CaT has been observed in Seyfert galaxies extensively. The most recent works are those of Boisson et al (2000), Jiménez-Benito et al (2001) and Nelson & Whittle (2001). In the last two works, the analysis of the CaT is combined with the Mg index (Mgb or Mg_2 at $\sim$ 5200 Å) that is a good metallicity indicator. They find that the CaT is very strong and the Mg lines are weak. For most of the Seyferts observed, the dilution by a power-law continuum can not simultaneously explain the strength of the CaT and the weakness of the Mg index. However, starbursts younger than 100 Myr can account for them because the stellar population is rich in RGSs that produce a strong CaT, and contribute to dilute the Mg lines that is produced by the old bulge stellar population. They conclude that, if not all, most of the Seyfert galaxies, including Sy1, are composite objects consistent of an AGN plus a starburst.

2.6.   Near-Infrared (NIR) diagnostics

In starbursts, the NIR light is dominated by the contribution of RSG and AGB stars. The CO index (at 1.62 and 2.29 μm) is also a good young stellar diagnostic because it depends on the spectral class, being strongest in supergiant stars (Kleinmann & Hall 1986). However, the strength of the index also depends on metallicity. However, as with the CaT, at the metallicity of bulges of early type galaxies that are the host of Seyfert nuclei, the surface gravity dependence dominates. There is, however, an additional concert with this stellar diagnostic which is that the band can be diluted by the radiation from the warm dust that surrounds the central AGN source. Even so, the CO index has been successfully used to detect starbursts in Sy1 galaxies, where the UV light method has failed. See for example the recent work by Schinnerer, Eckart & Tacconi (2001), that find a starburst in the inner 300 pc of the Sy1 NGC 3227 that contributes with 40% of the total continuum emission in the K band, although the UV image does not revealed it.

However, recent works have obtained contradictory results with respect to the estimation of the frequency of starbursts in Seyfert nuclei through the analysis of the NIR light. Ivanov et al (2000) find no evidence for strong contribution of starbursts in the nuclei of 16 Seyfert galaxies. In contrast, Oliva et al (1999) use the stellar index Si λ1.59 μm in addition to the CO λ1.62 and 2.29 μm to estimate the contribution of the non-stellar light and to measure the stellar

mass to light ratio at the H band (M/L_H). They find that 40% (5 of 13) of the Sy2s studied have M/L_H ratio similar to starburst galaxies, but Sy1s (8 objects studied) have all of them a M/L_H ratio similar to elliptical galaxies. Thus, they conclude that old and powerful starbursts are common in Sy2 but not in Sy1. This difference in terms of the young stellar population between Sy1 and Sy2 is in frontal conflict with the unification model of AGN. However, the conclusion is based on a very small sample of AGN. A study based on a larger sample is under way an it will help to check whether, as it has been proposed by Oliva and collaborators, starbursts and Seyferts are linked by an evolutionary sequence from starburst to Sy2 to Sy1.

2.7.   Radio Supernovas

Another useful tool to detect starbursts is the monitoring of Seyferts to search for supernovae. Explosions and evolution of compact supernova remnants in the nuclei of AGN have been proposed by Terlevich et al (1992) to explain the origin of the BLR. In fact, Aretxaga et al (1999) have explained the mutation of the classical Sy2 NGC 7582 into a Sy1 by the explosion driven by a compact supernova in its nucleus. They have also proposed this scheme to explain the variability and mutation of more than 12 relatively low luminosity AGN.

In particular, the monitoring at radio frequencies is a powerful tool to detect starbursts in very dusty AGN. This technique has the advantage of not suffering from obscuretion, and sets strong constraints on the properties of star formation in dusty systems. Colina et al (2001b) are monitoring several Seyferts galaxies with the VLA since 1998. They have reported the first detection of a radio supernova in the circumnuclear region of a Seyfert galaxy. In the year 2000, they detected at 8.4 GHz a very compact source (RSN J230315+0852.4) at 600 pc from the nucleus of the Sy1 galaxy NGC 7469. This supernova emits 7% of the total radio flux density within 1 Kpc of the AGN. Luminosity considerations indicate a supernova rate of 0.4 yr^{-1}. Even if the finding of Colina et al is not at all a proof for the starburst model of Terlevich and collaborator, the result indicates that the monitoring of Seyferts at radio is a potential tool to detect starbursts very close to AGN.

3.   Evidence of young stars in high luminosity AGNs: Radio Galaxies and QSOs

Last section has shown that nuclear starbursts are present at least in a significant fraction of the low luminosity regime of AGNs. Here, it is shown that young stars are also associated to lobe-dominated radio sources and very high luminosity QSOs.

3.1.   Radio Galaxies

FR II radio galaxies are the most luminous class of radio galaxies which host the most powerful and extended collimated radio-jets. Many of these galaxies show a spatially extended UV morphology that is aligned with the major axis of their radio emission. The origin of this emission has been attributed to: 1) dust and electron scattered light from an anisotropic radiation produced by the hidden

AGN (in the spirit of the unification model of AGN, Tadhunter 1987), and 2) recent star formation triggered by the radio source (De Young 1981). Even, there are enough proofs in favor of the unification model hypothesis, there are also many cases where the excess of blue color can only be explained by young stars (e.g. Tadhunter, Dickson & Shaw 1996). A strong evidence is shown in the high-z radio galaxy 4C 41.17 (Dey et al 1997). It has been found that UV light that is spatially aligned with the radio axis is unpolarized, and its spectrum shows wind P-Cygni and photospheric UV lines that are produced only by massive stars. A powerful starburst with a star formation rate of 140-1100 M⊙ yr^{-1} can account for the UV continuum luminosity.

Aretxaga et al (2001) have observed young stars in powerful nearby radio galaxies. They use the HOBS as a stellar diagnostic, and they detect these lines in absorption in 6 of the 7 galaxies observed. Their strength is much larger than that found in normal galaxies and they indicate the presence of a stellar population younger than 1 Gyr. A starburst and post-starburst stellar population have been also detected in radio (loud and quiet) galaxies selected with very strong far-infrared emission (Tran et al 1999).

3.2.   QSOs and QSO's hosts

Now, there is at least circumstantial evidence that suggests that there is a connection between starbursts and QSO activity. In fact, external processes such as galaxy interactions or mergers, have to be invoked to sustain the high rate of gas accretion required by luminous AGNs during the life time of the QSO activity ($\sim 10^8$ yr). Star formation could be triggered in the QSO's host and just at the nucleus when the gas is transported and compressed to the center to feed the AGN. Ultra-luminous far infrared galaxies (ULIRGs) may provide a clear link between galaxy mergers, starbursts and QSOs. In these objects AGN and starburst activity co-exists together, and the dominance of one of these two types of activity depends on the advance state of the merger (Veilleux et al 2001). Starbursts have been found in the host of many nearby QSOs (Canalizo & Stockton 2001). They have been revealed by the detection of Balmer absorption lines in the surrounding of the AGN or nebular HII emission. The ages estimated derived for the starburst population range from a few Myr old (current star formation) to post-starburst ages ($\leq$ 300 Myr). All these galaxies show clear signs of interactions and major mergers, that indicate a connection between interactions, starbursts and QSO activity. Probably, the most spectacular example is in the QSO UN J1025-0040 observed by Brotherton et al (1999). The optical spectrum displays the broad Mg II $\lambda2800$ emission line and a strong blue continuum characteristic of a QSO and at the Balmer jump the higher order Balmer lines in absorption. A stellar component of about 400 Myr old with mass of 10^{11} M⊙ is responsible for 70% of the unresolved nuclear light. This result proves that powerful QSOs can co-exist with also very powerful starbursts just at the center of galaxies.

4.   Impact of the starbursts on the energetics of Seyferts

Previous sections have shown that there is strong evidence of the co-existence of starbursts and AGN in the center of galaxies. However, the key point is to

know whether the starbursts make an impact on the energetics of the AGN or if they can even dominate over the accretion processes. Here, I concentrate to answer these points in Sy2 galaxies. A systematic study on Sy1s, similar to the one done in Sy2s, is under way and we expect to be soon in conditions to check whether the same conclusions are sustained for more luminous AGN.

We (GD01; CF01) have found that the most powerful Sy2 galaxies that harbor a starburst have lower excitation (measured by [OIII] $\lambda 5007$/Hβ), cooler far-infrared colors (f_{25}/f_{60}) and larger mid (measured by the IRAS band at 12 μm, L_{12}) and far-infrared luminosities than the Sy2s that show an old nuclear stellar population. These differences are expected if a starburst makes a substantial contribution to the heating of the dust and to the ionization of the gas in the former set of nuclei, but not the latter. We found that all the Sy2s studied that have L_{FIR} above 2×10^{10} L$\odot$ also harbor a starburst. Then, luminous far-infrared Sy2s may owe much of their luminosity to the starburst. Another conclusion is that the Sy2s with most powerful nuclei may be also associated with most powerful starbursts, because the 12 μm luminosities (which arguably measures the hot gas heated by the AGN, Spinoglio & Malkan 1989) are also larger in the Sy2s with young and intermediate age population. This luminosity link between the AGN and the starburst activity may be related to a common causal effect, that could be the presence of companions. In fact, Storchi-Bergmann et al (2001) have found that 60% of the Sy2 with nuclear starbursts have a close companion or are in mergers, unlike to the 20% of the Sy2 nuclei with old stellar population.

Another key point is the impact of the starburst on the ionization of the gas. CF01 have found a strong correlation between the nuclear nebular Hβ luminosity in Sy2 galaxies and the optical continuum provided by the young stellar population or/and the FC continuum. This correlation is similar to the Yee (1980) and Shuder (1981) correlation that extends from Sy2s to QSOs. This correlation for Sy2s, that is unexpected within the prediction of the unification model of AGN, may be driven by presence of nuclear starbursts in Sy2s rather than by the accretion process. It also indicates that the starburst has a substantial impact on the ionization of the gas. In fact, the Hβ and [OIII] nebular lines in the Sy2s with nuclear starbursts are resolved into two components. The broad component has excitation much larger than the narrow one and it is similar to the excitation measured in the Sy2 nuclei with old stellar population. If the narrow component, that has excitation similar to typical starbursts, is produced only by massive stars, thus, the Hβ fluxes indicate that the starburst contributes between 30% and 80% of the total ionization. Thus, the starbursts have a significant impact on the emission line ratio of these Seyfert 2 nuclei.

Levenson, Weaver & Heckman (2001) have analyzed the X-ray spectra and images of the Sy2 galaxies that contain starbursts to estimate the impact of the recent star formation in X-ray. They find that although all Seyferts of the sample show AGN at X-ray, the accretion process itself can not account for the total X-ray emission. The emission is extended on spatial scales of $\sim$10 Kpc, which is produced by outflows driven by the starbursts. On the other hand, the hard X-ray nuclear spectra are heavily absorbed, indicating that the starbursts contribute also to the obscuretion of the AGN.

5. Implications for the Unification Models of AGNs

Our works (SB00; GD01 and CF01) in Sy2 galaxies indicate that most of the most powerful Sy2 nuclei can be grouped into two classes, those with starbursts and those with an old population. This segregation poses important questions: are there two different classes of Seyfert 2?, do all Seyfert 2 contain a hidden Seyfert 1 nucleus? In fact, the infrared colors and excitation of the two groups are different. Nuclei with old population starbursts have [OIII]/Hβ (~ 10) similar to Sy1, and f_{25}/f_{60} (~ 0.4) larger than the color suggested by Heisler, Lumsden & Bailey (1997) for Sy2 with no detected hidden broad emission lines (HBLR) in polarized light. In contrast, Sy2 with starbursts have lower excitation and cooler far-infrared colors. These differences suggest that there may be two classes of Sy2: Sy2s that have a hidden Sy1 nuclei and real Sy2 with non-HBLR that may evolve from starbursts. In this respect, Gu et al (2001) have compiled all the available data in the literature about Seyfert galaxies with circumnuclear starbursts (in spatial scales from few 100 pc to several kpc). They find that the Sy2 with HBLR have properties similar to Sy1 and those non-HBLR have properties similar to starbursts. To ckeck this result, I have compiled the spectropolarimetry observations of the samples of SB00 and GD01; 16 over 35 of the two samples have been observed, HBLRs have been detected in 9 of these objects. Of these 9, 5 have nuclear starbursts and 4 have old population. On the 7 objects with non-HBLR detection, 3 have starbursts and 4 old population. This comparison suggests that there is no strong anti-correlation between the presence of a hidden Sy1 nucleus and a nuclear starburst. This is at odds with a model in which one class of Sy2 nuclei are powered by hidden Sy1 nuclei and another class is powered by a nuclear starburst. However, Tran (2001) has suggested the existence of two intrinsically different populations of Sy2 galaxies: one harboring a hidden Sy1 nucleus and the other pure Sy2 without a Sy1 in which the energetics may be dominated by a starburst component. Our previous results indicate that if in fact there are two different classes of Sy2 nuclei, a starburst component may be present in both classes. However, the starburst may also contribute to obscure the hidden Sy1. An extreme example is found in the galaxy NGC 6221 (Levenson et al 2001). Its nuclear optical spectrum is like a starburst, but its X-ray emission is like a Sy1 showing continuum variability, a broad FeII K line and a power law continuum.

   Are there differences in terms of star formation activity between Sy1 and Sy2? Gu et al (2001) based on their literature compilation find that there is a larger fraction of star formation in Sy2 than in Sy1. On the other hand, based on a small statistical sample, Oliva et al (1999) arrive at the same conclusion through the estimation on the M/L_H ratio. The 'standard' unification model of AGN can not account for the apparent enhanced star formation activity in Sy2 with respect to Sy1. As an alternative, they proposed (it was also proposed a long ago by Heckman et al 1989) an evolutionary scheme in which Sy2 evolve into Sy1. In this scheme, starbursts obscure the AGN, and when the massive stars explode as supernova destroy the dust that enshrouds the AGN, exposing a bright Sy1 nucleus. In this sense, Heckman et al (1989) proposed the Sy2 galaxies as the missing link between ULIRGs and QSOs. However, I think that there is not yet a strong evidence that the fraction of *nuclear* starbursts is larger in Sy2 than in Sy1, in particular considering that it is much difficult to detect nuclear

starbursts in Sy1 than in Sy2 due to the blinding glare of the AGN in Sy1 that masks most of the starburst diagnostics used in Sy2 nuclei. However, an evolutionary scenario in which the starburst and the AGN are relatively long-lived, and the Sy2 with starburst can evolve to Sy2 may be an additional ingredient to the pure geometry consideration of the standard unification model. Nuclei like Mrk 78, that has a pronounced post-starburst population, may represent the intermediate state. This picture suggests that nuclear starbursts may be an integral part of the AGN phenomenon, and they are triggered at the outskirt of the molecular torus where gas at a few hundred parsecs of the nucleus may be accumulated and compressed to feed the AGN.

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